Rainfall, Streamflow, and Water-Quality Data During Stormwater Monitoring, Halawa Stream Drainage Basin, Oahu, Hawaii, July 1, 2002 to June 30, 2003

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By Stacie T.M. Young and Marcael T.J. Ball

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Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=1.8(°C) + 32$$

Water-Quality Abbreviations:
mg/L, milligrams per liter
µg/L, micrograms per liter
µg/kg, micrograms per kilogram

Abbreviations:
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C)

Datums
Vertical coordinate information is referenced relative to mean sea level.
Horizontal coordinate information is referenced to Old Hawaiian Datum.

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Abstract

Storm runoff water-quality samples were collected as part of the State of Hawaii Department of Transportation Stormwater Monitoring Program. This program is designed to assess the effects of highway runoff and urban runoff on Halawa Stream. For this program, rainfall data was collected at two sites, continuous streamflow data at three sites, and water-quality data at five sites, which include the three streamflow sites. This report summarizes rainfall, streamflow, and water-quality data collected between July 1, 2002 to June 30, 2003.

A total of 28 samples were collected over five storms during July 1, 2002 to June 30, 2003. For two of the five storms, five grab samples and three flow-weighted time-composite samples were collected. Grab samples were collected nearly simultaneously at all five sites, and flow-weighted time-composite samples were collected at the three sites equipped with automatic samplers. The other three storms were partially sampled, where only flow-weighted time-composite samples were collected and/or not all stations were sampled. Samples were analyzed for total suspended solids, total dissolved solids, nutrients, chemical oxygen demand, and selected trace metals (cadmium, copper, lead, and zinc). Grab samples were additionally analyzed for oil and grease, total petroleum hydrocarbons, fecal coliform, and biological oxygen demand. Quality-assurance/quality-control samples, collected during storms and during routine maintenance, were also collected to verify analytical procedures and insure proper cleaning of equipment.

INTRODUCTION

The State of Hawaii Department of Transportation (DOT) Stormwater Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2002) was implemented on January 1, 2001, to monitor the Halawa Stream drainage basin, Oahu, Hawaii. The Stormwater Monitoring Program Plan was designed to fulfill part of the permit requirements for the National Pollutant Discharge Elimination System program and is revised yearly. The Stormwater Monitoring Program Plan includes the collection of rainfall, streamflow, and water-quality data at selected sites in the Halawa Stream drainage basin.

This report summarizes water-quality data collected by the U.S. Geological Survey (USGS) as part of the Stormwater Monitoring Program Plan. This report presents rainfall, streamflow, and water-quality data collected from July 1, 2002 to June 30, 2003. Descriptions of the sampling techniques are included with the water-quality data.

Five storms were sampled during July 1, 2002 to June 30, 2003. A total of 28 samples were collected during the five storms. In addition to these samples, 12 quality-assurance/quality-control (QA/QC) samples were collected: 8 samples were collected concurrently with storm samples during four of the storms, and 4 samples were collected between storms during routine cleaning of the sampling equipment. Water-quality data for the QA/QC samples are not

published in this report, but are available upon request.

DATA-COLLECTION NETWORK

Stream-stage, stream-discharge, rainfall, and water-quality data were collected at selected sites in the Halawa Stream drainage basin (fig. 1). Rainfall data were collected at two sites, 212428157511201, North Halawa Valley rain gage at H-3 tunnel portal (abbreviated to Tunnel rain gage) and 212304157542201, North Halawa rain gage near Honolulu (abbreviated to Xeriscape garden rain gage). Streamflow data were collected at three sites in North Halawa Valley since 1998, 1983, and 2001, respectively; 212353157533001, Storm drain C; streamflow-gaging station 16226200, North Halawa Stream near Honolulu (abbreviated to Xeriscape garden); and 16226400, North Halawa Stream at Quarantine Station (abbreviated to Quarantine station). Rainfall and streamflow data were collected using variable time-steps depending on rainfall or streamflow rates. The data from the two rain gages and the three streamflow-gaging stations are transferred daily to the USGS database using cellular-phone telemetry and can be viewed at http://hi.water.usgs.gov/ by using the site numbers.

Water-quality data were collected at five sites (fig. 1): 212356157531801, North Halawa Stream at Bridge 8 near Halawa (abbreviated to Bridge 8); Storm drain C; Xeriscape garden; Quarantine station; and 16227100, Halawa Stream below H-1 (abbreviated to Stadium). The Bridge 8 site is about 0.75 mi above the discharge point of Storm drain C on North Halawa Stream. Storm drain C collects runoff from an approximately 4 mi length of freeway from the tunnel portal to mid-valley and discharges directly to North Halawa Stream (fig. 1). The Xeriscape garden gage is directly upstream from a light-industrial area near North Halawa Stream, and about 0.75 mi downstream of the discharge point Storm drain C. The Quarantine station is about 1 mi downstream of Xeriscape garden and near the downstream end of the light-industrial area that borders the North Halawa Stream. The Stadium site is about 0.5 mi downstream of the Quarantine station, below the confluence of North and South Halawa Streams, downstream from the crossing of H-1 freeway, and directly upstream from the mouth of Pearl Harbor. Water-quality data have been previously collected at Storm drain C (1998–present), Xeriscape garden (1983–present), and Stadium (1988–present) by the USGS as part of the H-3 freeway construction monitoring study and can be viewed at http://waterdata.usgs.gov/hi/nwis/qwdata using the site numbers.

WATER-QUALITY SAMPLING TECHNIQUES

Water-quality samples include grab samples collected manually, grab samples collected by the automatic sampler, and flow-weighted time-composite samples collected by the automatic sampler.

Sampling requirements.--The DOT Stormwater Monitoring Program Plan states that water-quality samples will be collected at least once per quarter during periods of storm runoff from each of the five water-quality monitoring stations (fig. 1). The plan also states that efforts will be made to sample from all five water-quality monitoring stations during a single storm, and if a storm does not occur during a quarter, no samples will be collected.

A complete storm sample consists of five grab samples, three flow-weighted time-composite samples, and three QA/QC samples. However, some storms are brief and do not produce adequate runoff to sample all five sites and collect all eight-storm samples. In practice, these storms have been sampled as thoroughly as possible, and analyzed for as many constituents as practical.

Storm criteria.--The U.S. Environmental Protection Agency's (USEPA) Storm Water Sampling Guidance Manual (U.S. Environmental Protection Agency, Office of Water, 1993) provides guidelines for stormwater sampling criteria. The first criteria requires at least 0.1 in. of accumulated rainfall. Rainfall accumulation have exceeded 0.1 in. at the Tunnel rain gage and Xeriscape garden rain gage when stormwater sampling was conducted. The second criteria requires that samples be collected only for storms preceded by at least 72 hours of dry weather. The second criteria would prevent sampling of most storms on North Halawa Stream because the Halawa Stream drainage basin, as well as many

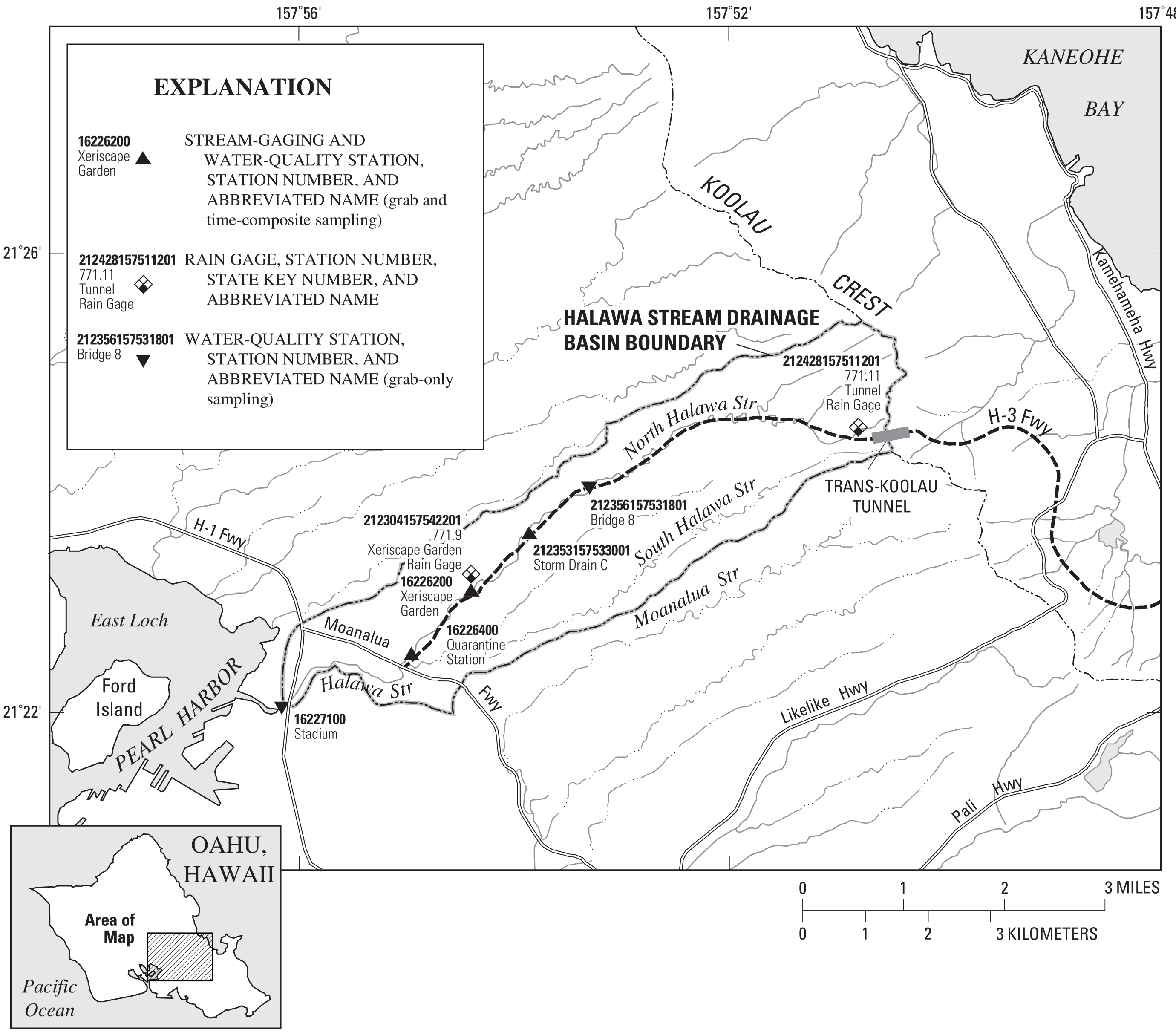

Figure 1. Stream-gaging stations, rain gages, and water-quality sampling sites in the Halawa Stream drainage basin, Oahu, Hawaii.

other parts of the island, receive tradewind showers almost daily.

In practice, criteria for sampling the stream and storm drain are based on the rate of rainfall accumulation and the rise of stage in Storm drain C, Xeriscape garden, and Quarantine station. Each automatic sampler is triggered at predetermined stream-stage thresholds, depending on the site. The automatic samplers at Storm drain C, Xeriscape garden, and Quarantine station collect samples at stages that correspond to discharges greater than 3 ft^3/s, 40 ft^3/s, and 41 ft^3/s, respectively.

Sample collection.-- In general, grab samples were collected manually using isokinetic, depth-integrating samplers and equal-width increment (EWI) sampling techniques (Wilde and others, 1998). The sampler is made of high-density polyethylene (HDPE) and collects water in an isokinetic manner, in which water enters the sampler at the same velocity as the stream. The EWI sampling techniques utilizes evenly spaced sampling points along the cross section of the stream, which are proportionately sampled based on the discharge of each increment, and combined in an HDPE churn.

An EWI sample is practical when depths are greater than 0.5 ft and the stream is wadeable. During high-discharge storms, streams were not waded for safety reasons. However, the stream was well mixed during high-discharge at each site such that the EWI method was not necessary. At such times, the grab sample was collected by an isokinetic sampler at a single vertical section of the estimated centroid of flow of the stream. Each sub-sample from the single-vertical technique was composited in an HDPE churn.

A flow-weighted, time-composite sample was created by combining, in a HDPE churn, all or part of the samples collected by the automatic sampler. The desired volume of water from each sample is proportional to the stream discharge volume between sample collection times.

Composite samples were collected over a time period that sometimes lasted several hours using an automatic sampler. Automatic samplers collect water from a fixed point in the stream channel after pre-determined stage thresholds are met. The automatic samplers have a capacity of 24 bottles. When the first threshold was met, the automatic samplers were programmed to sample water every 2 minutes for the first five samples, and then every 15 minutes. When a higher, second threshold was met, the automatic samplers were programmed to sample water every 7 minutes.

The first five samples from the automatic sampler were collected at 2-minute intervals and can be combined and analyzed as a grab sample when grab samples cannot be collected manually. The first three of these five samples were collected in teflon bags. In the event that a manual grab sample cannot be collected, the samples in teflon bags may be used for oil and grease (O+G) and total petroleum hydrocarbon (TPH) analyses. The remaining 21 samples were collected in low density polyethylene (LDPE) bags.

Using samples from the automatic sampler for grab samples is not ideal for many of the analyses, however. Residues that contain oil and grease and total petroleum hydrocarbons tend to stick to non-teflon, non-glass surfaces, potentially changing the concentration of the constituents when transferring from container to container. Additionally, some constituents require the sample to be chilled prior to analysis or analyzed within a certain time after collection, known as a holding time. The automatic samplers were not equipped with refrigeration units, and thus holding times for some constituents may have been exceeded.

Samples collected by the automatic sampler (automatic samples) may be used in lieu of and/or in addition to manual grab samples. Thus, there may be more than five grab samples in a sample set or more than one grab sample at a site. Situations, in which automatic samples are used in lieu of manual grab samples, are when the automatic sample times are far apart or when a manual grab sample could not be collected because of insufficient runoff at the time of the site visit. When the sample times, at which the sample bottles were filled, are separated by a couple hours, the sample bottles were not combined into a composite sample because it would not represent the early part of the storm.

If the first five samples were collected from the same peak, these samples would be representative of a first flush sample and would be analyzed as a grab sample. The first sample bottle would be for O+G analyses and the second sample bottle for TPH analyses. The other three sample bottles would be combined and analyzed for total suspended solids (TSS), total dissolved solids (TDS), nutrient, chemical oxygen demand (COD), and selected trace metals (cadmium, copper, lead, and zinc). Fecal coliform (FC) and biological oxygen demand (BOD) would not likely be analyzed in this case because the holding times for these constituents would likely be exceeded.

Determination of discharge.--At the Bridge 8, Storm drain C, Xeriscape garden, and Quarantine station sites, discharge associated with each sample was determined using a streamflow rating, created for the site, or by measurement using a current meter. Streamflow ratings were developed by measurements and computer modeling, and verified by subsequent measurements. At the Stadium site, the wide and curving concrete-lined channel and shallow and swift streamflow precluded development of an accurate streamflow rating. Discharge at this site was measured using a current meter, or at higher flows, using float-measurement techniques, in which floating bottles were timed over a known distance to determine velocity, and the area of the cross-section was estimated by the depth of water and surveyed dimensions of the channel. USGS practices for making discharge measurements and rating streamflow ratings can be found in Rantz (1982).

An average-discharge value was calculated for each composite sample. The average-discharge value was equal to the total volume of water that flowed by the gaging station during sample collection, divided by the total elapsed time during sample collection (for only the samples used for the composite). To determine the volume of water that passed the station for each sample, the discharge at the time of sample collection was multiplied by the elapsed time between each sample collected. The same time increment between the first and second samples was assigned to the first sample. These volumes were summed, and the total volume was divided by the sum of all the time increments. This method overestimates average discharge if the stream discharge was increasing during sample collection, and underestimates average discharge if the stream discharge was decreasing.

Measured, streamflow rating, and averaged discharge values are reported to appropriate number of significant figures. These discharge values and the corresponding values of constituent concentration are used to compute loads. Reported discharge values and the calculation of loads are discussed in appendix A.

Sample processing, analysis, and quality-assurance/quality control.--USGS water-quality sampling methods (Wilde and others, 1998) were followed to prevent possible contamination during sample processing. Both grab and composite samples were processed using churns to mix and suspend sediment while delivering the sample to specific bottles for the various constituent analyses. The time assigned to each grab and composite sample is the median time of the sample collection.

As required by the DOT Stormwater Sampling Program Plan, each composite and grab sample was analyzed for temperature, pH, specific conductance, TSS, TDS, nutrients, COD, and selected trace metals (cadmium, copper, lead, and zinc). Each grab sample is additionally analyzed for O+G, TPH, FC, and BOD. USGS personnel made field measurements of temperature, pH, and specific conductance. The minimum reporting levels for each of the analyzed properties and constituents are listed in table 1 and are based on values published by the USGS National Water Quality Laboratory (NWQL). Calculated values, organic nitrogen and total nitrogen, do not have minimum reporting levels. More information about minimum reporting levels and how they are determined by NWQL can be found in Childress and others (1999).

Table 1. Minimum reporting levels of properties and constituents for all samples collected from Halawa Stream drainage basin from July 1, 2002 to June 30, 2003, Oahu, Hawaii

[std., standard; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; °C, degrees Celsius; µg/L, micrograms per liter; --, no minimum reporting level, computed value; MPN/100 mL, most probable number (of colonies) per 100 milliliters]

Property or constituent	Minimum reporting levels
pH	0.1 std. units
Specific conductance	1.0 µS/cm
Temperature	0.5 °C
Total suspended solids	10 mg/L
Total dissolved solids	10 mg/L
Total nitrogen[a]	--
Organic nitrogen[b]	--
Nitrogen ammonia dissolved	0.041 mg/L
Nitrogen, total organic + ammonia[c]	0.10 mg/L
Nitrogen, nitrite + nitrate dissolved	0.060 mg/L
Phosphorus dissolved	0.035 mg/L
Total phosphorus	0.040 mg/L
Chemical oxygen demand	10 mg/L
Total cadmium	0.035 µg/L
Total copper	0.06 µg/L
Total lead	0.06 µg/L
Total zinc	2 µg/L
Oil and grease	7 mg/L
Total petroleum hydrocarbons	2 mg/L
Biological oxygen demand	1 mg/L
Fecal coliform	2 MPN/100mL

[a]Total nitrogen is calculated by adding nitrogen, total organic + ammonia (Kjeldahl) to nitrite+nitrate, dissolved.

[b]Organic nitrogen is calculated by subtracting ammonia, dissolved, from nitrogen, total organic + ammonia (Kjeldahl).

[c]Nitrogen, ammonia dissolved, plus total nitrogen, is total Kjeldahl nitrogen.

FC and BOD analyses were performed by Aecos Incorporated, a private laboratory on Oahu. QA/QC practices at Aecos Incorporated are conducted, but are not published. All other analyses were performed at the USGS NWQL, in Denver, Colorado. The methods used for analyses of all water-quality constituents and quality control practices at NWQL are documented in Friedman and Erdmann (1982), Fishman and Friedman (1989), Pritt and Raese (1992), Patton and Truitt (1992) and Fishman (1993).

Three different QA/QC samples were collected at designated sites during each storm. A field duplicate, which is a sample that is split into two during sample processing, was collected at Bridge 8. A laboratory duplicate, which is a sample that is analyzed twice at the laboratory, was collected at Quarantine station. A spiked sample, created by a part of the storm sample and spiked at the NWQL with a known quantity of analyte, was collected at Xeriscape garden.

During the interim between storms, non-dedicated and non-disposable equipment, such as churns, isokinetic samplers, automatic sampler intake lines, and teflon automatic sampler bottle liners, were cleaned following procedures in Wilde and others (1998). Field blank samples were collected once per quarter. Inorganic blank water (IBW), free of inorganic constituents, was passed through this equipment and collected. The IBW field samples were analyzed for the same inorganic constituents as the storm samples.

RAINFALL AND STREAMFLOW DATA

Hydrographs of daily rainfall and daily mean streamflow data for the period July 1, 2002 through June 30, 2003 are shown in figure 2. A total of 87.2 in. of rain was recorded at the Tunnel rain gage and 23.2 in. of rain was recorded at Xeriscape garden rain gage between July 1, 2002 through June 30, 2003.

Days with daily rainfall values greater than 2.4 in. at the Tunnel rain gage and daily rainfall values greater than 0.3 in. at the Xeriscape garden rain gage resulted in sufficient runoff for collecting of a complete storm sample. For lower rainfall events, only a parital storm sample was collected. Complete storm samples were collected on January 31, 2003 and February 14, 2003. Xeriscape garden and Tunnel rain gage had daily rainfall values of 3.6 in. and 0.4 in. on January 31, 2003 and 6.8 in. and 0.7 in. on February 14, 2003. The highest daily rainfall at the Tunnel rain gage was 6.8 in. on February 14, 2003. The highest daily rainfall at the Xeriscape garden rain gage was 1.9 in. on November 16, 2002.

Halawa Stream is an intermittent stream. The longest record of streamflow and water-quality data is from the Xeriscape garden gage, which was part of a network of gages for the H-3 Highway construction project (1983–2000). From the flow-duration curve of Xeriscape garden (fig. 3), zero flow at this station occurs about 30 percent of the time and the stage at which the automatic sampler threshold is exceeded occurs about 3 percent of the time. At Xeriscape garden streamflow-gaging station, the highest daily mean discharge was 92 ft^3/s on February 14, 2003. The longest period of zero flow at this station was for 6 weeks during the months of May and June in 2003. At the Quarantine station gaging station, the highest daily mean discharge was 37 ft^3/s on January 31, 2003. The longest period of zero flow at this station was for 8 weeks during the months of May and June in 2003. For Storm drain C, the highest daily mean discharge was 2.3 ft^3/s on February 14, 2003. The longest period of no flow at this station was for 12 days during the month of May.

STORMWATER SAMPLING: CONDITIONS AND RESULTS

During the period July 1, 2002 through June 30, 2003, at least seven storms occurred with sufficient runoff to trigger the automatic samplers at the predetermined thresholds. Of these storms, five were sampled: October 14–15, 2002, January 15 and 30–31, 2003, February 14, 2003, and March 16–17, 2003.

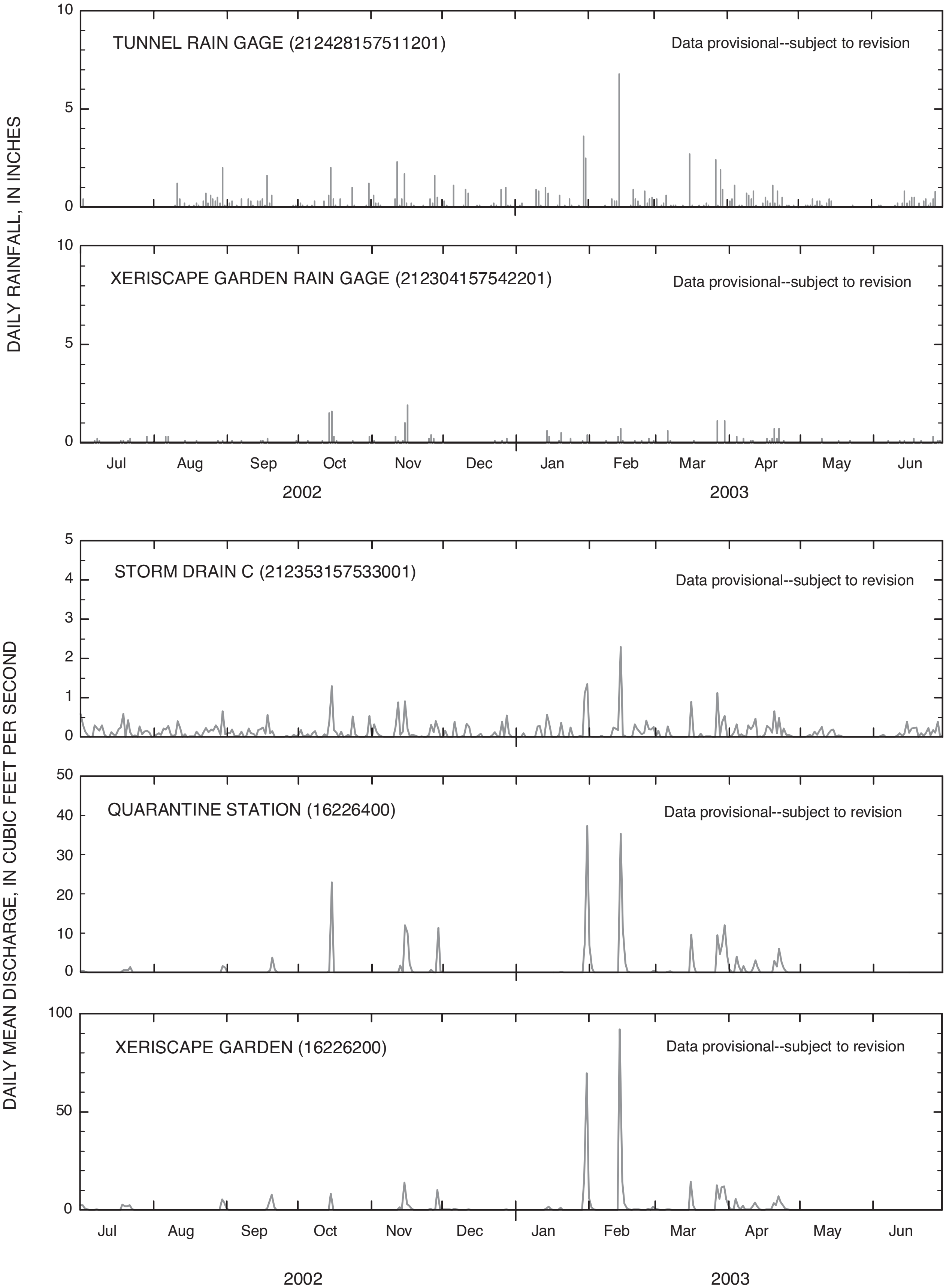

Figure 2. Rainfall and stream discharge for stations within the Halawa Stream drainage basin, Oahu, Hawaii, for July 1, 2002 to June 30, 2003.

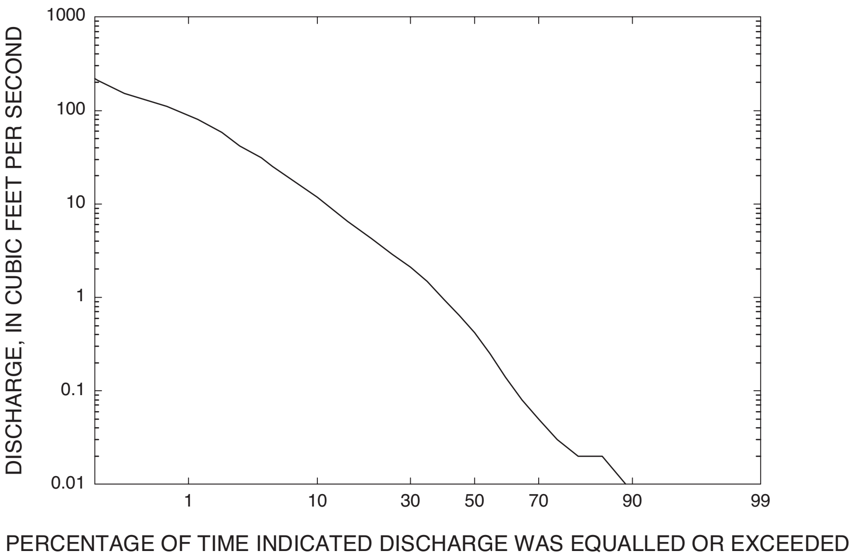

Figure 3. Flow duration curve of daily flows for station 16226200, North Halawa Stream at Xeriscape garden, Oahu, Hawaii.

Third Quarter 2002 – July 1 to September 30, 2002

No storms were sampled during the third quarter 2002. Hydrologic conditions for the quarter are shown in figure 4 for Storm drain C, Xeriscape garden, and Quarantine station for the period of July 1, 2002 to September 30, 2002. A short rainfall event caused a peak in discharge on the evening of September 18, 2002 at 21:15. The automatic sampler threshold was exceeded only at Storm drain C. Because only 3 sample bottles were collected at Storm drain C, when at least 5 are required, and the sample holding times exceeded 12 hours, no storm samples were processed. Grab samples could not be collected because there was insufficient flow in the storm drain.

Another short rainfall event caused a peak in discharge on the evening of September 20, 2002 at 18:45 (fig. 4). Automatic sampler thresholds were exceeded only at the Xeriscape garden and Quarantine station sites. The automatic sampler at Xeriscape garden and Quarantine station sites collected 6 and 3 sample bottles, respectively. No samples were processed at either site due to insufficent sample bottles collected at Quarantine station and sample holding times exceeded 12 hours at both sites

Fourth Quarter 2002 – October 1 to December 31, 2002

Storm of October 14–15, 2002

During fourth quarter 2002, the October 14–15 storm was the only one sampled. Hydrographs of streamflow at Storm drain C, Xeriscape garden, and Quarantine station during the storm are shown in figures 5, 6, and 7, respectively. Beginning and end times for composite-sample collection are displayed on the hydrographs (figs. 5–7).

A total of four composite samples were collected, two from Storm drain C and one each from Xeriscape garden and Quarantine station. No grab samples were collected during this storm. Samples were analyzed for all constituents listed in the Stormwater Monitoring Program Plan (State Department of Transportation, 2000). Discharge, temperature, pH, and specific-conductance values from field measurements and constituent concentrations and average loads for the four composite samples are shown in appendix B.

Storm drain C.--The automatic sampler collected a total of 17 samples during the storm. Two flow-weighted time-composite samples were created. The first composite sample consisted of the first five samples collected from the first peak of discharge, which was considered representative of a first flush. The peak discharge was 8.5 ft^3/s at 16:06 on October 14, 2002.

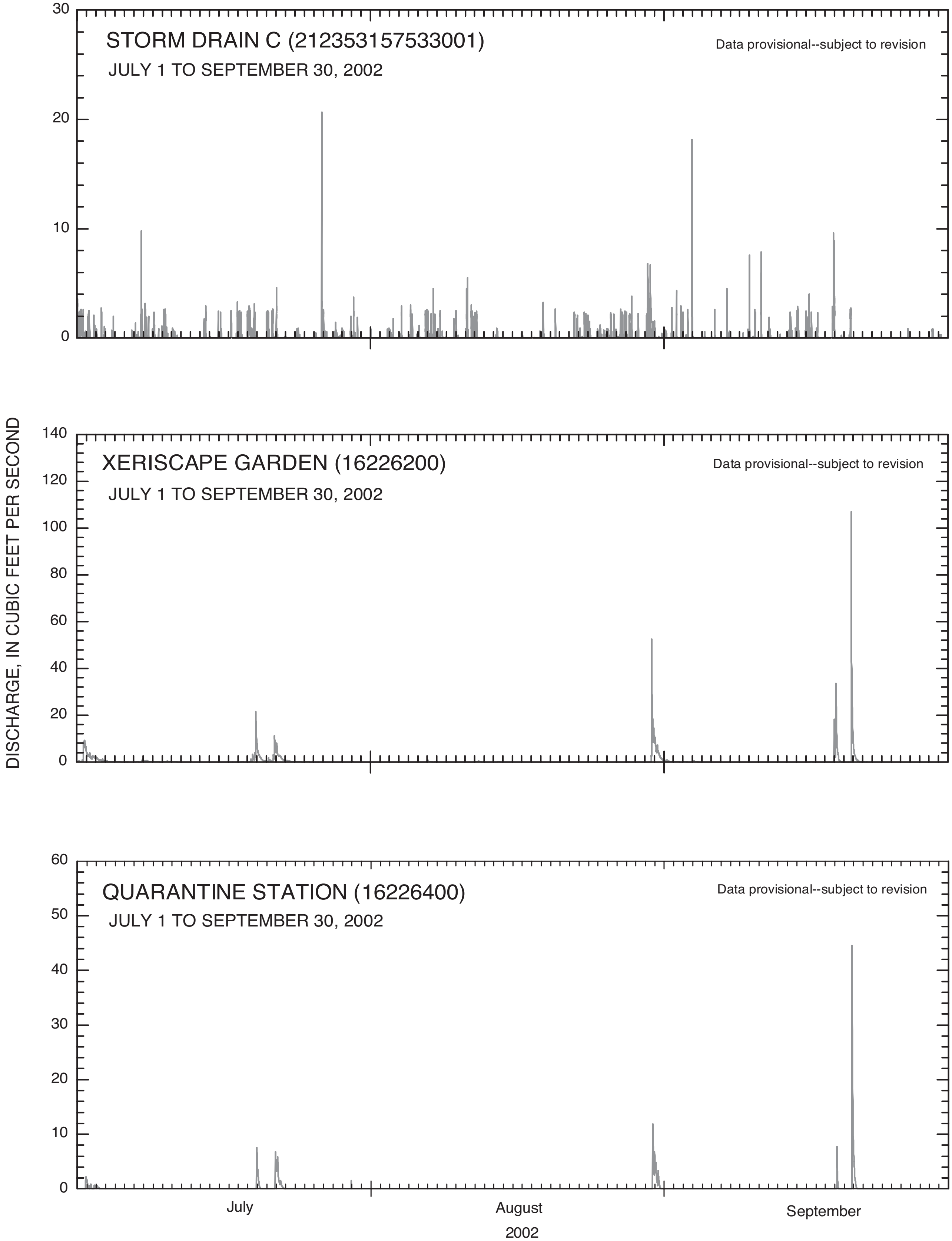

Figure 4. Stream discharge at Storm drain C, Xeriscape garden, and Quarantine stations for July 1 to September 30, 2002, Oahu, Hawaii.

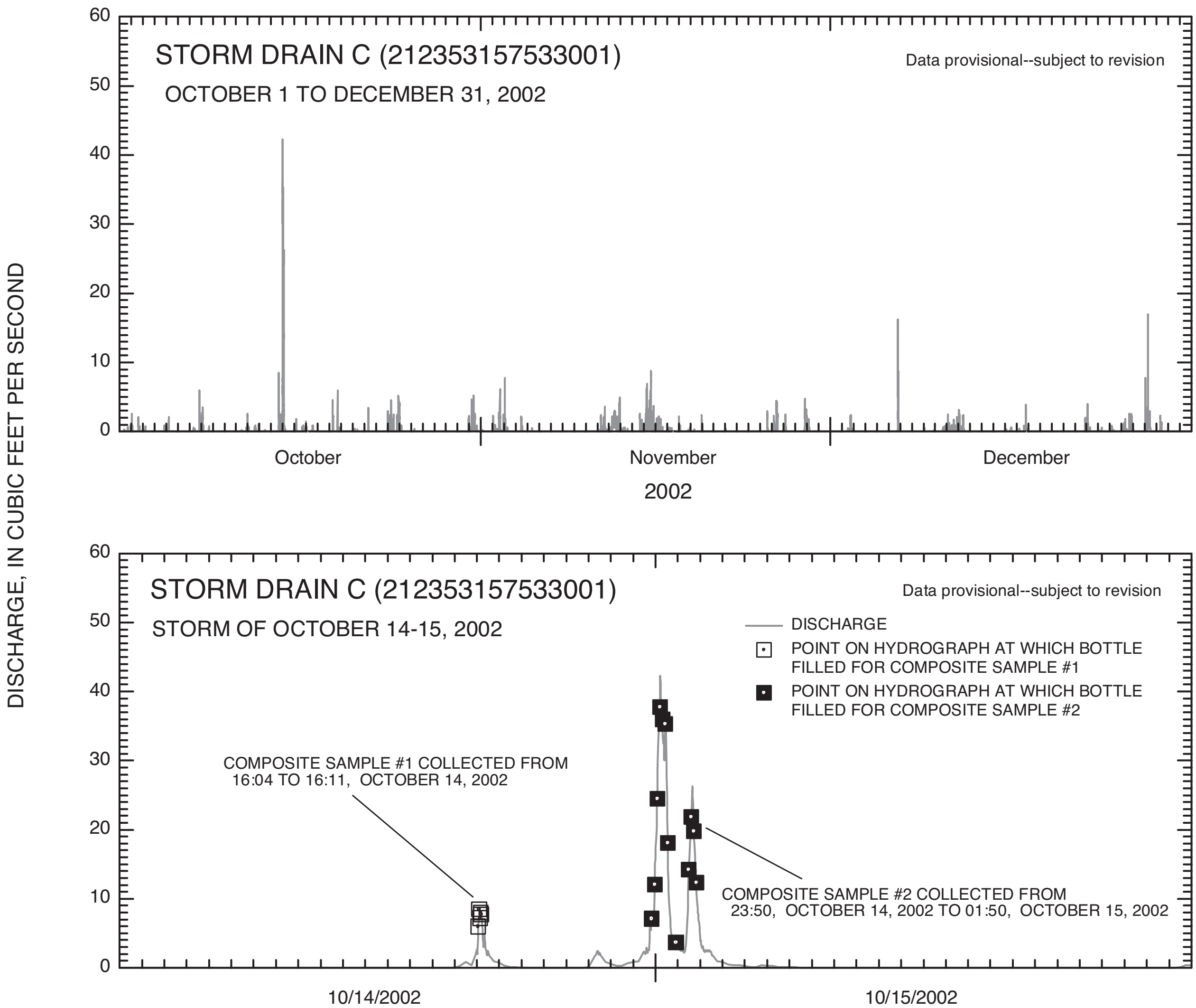

Figure 5. Stream discharge at Storm drain C station (212353157533001) for October 1 to December 31, 2002, and detail of the 2-day period from October 14 to October 15, 2002.

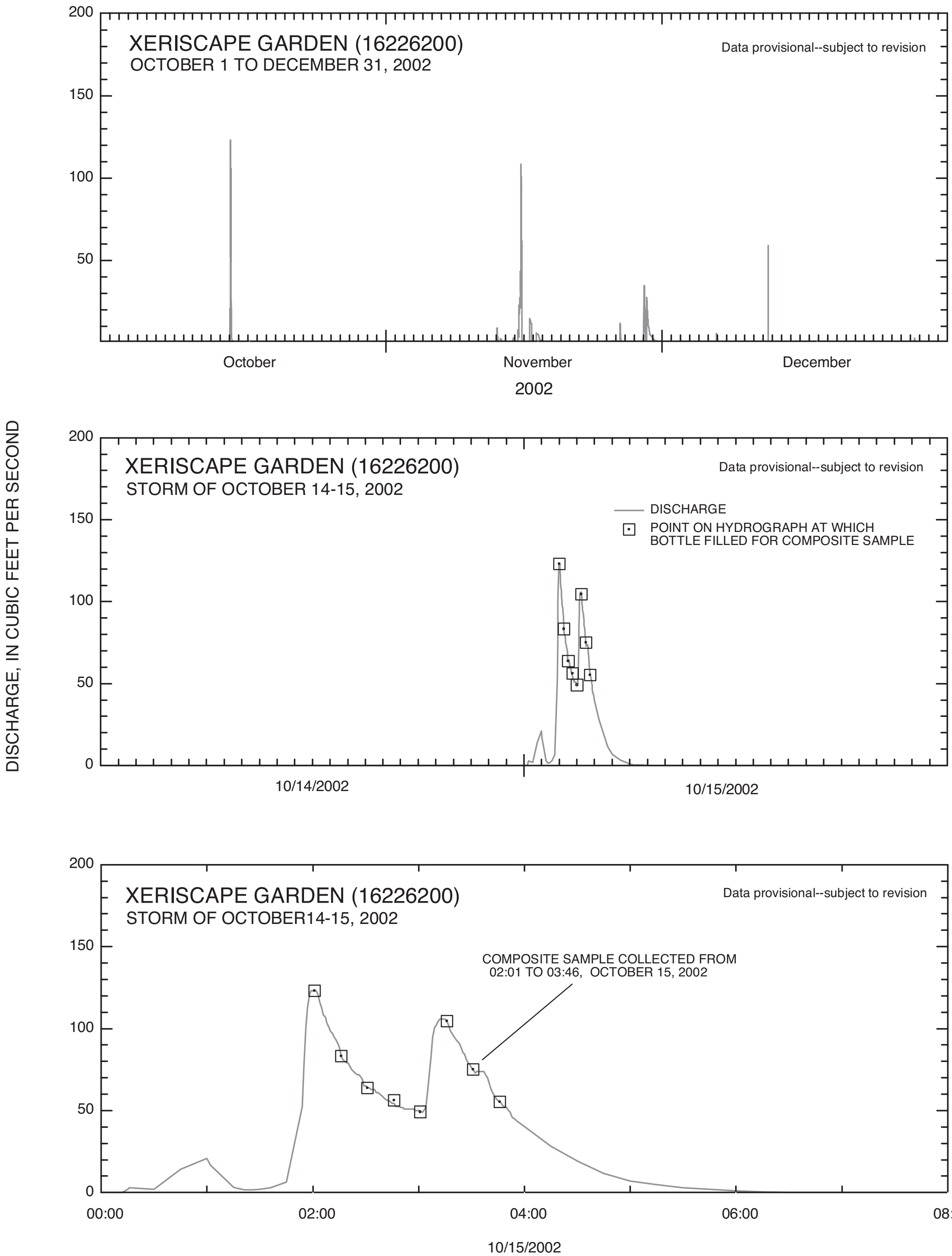

Figure 6. Stream discharge at Xeriscape garden station (16226200) for October 1 to December 31, 2002; detail of the 2-day period from October 14, 2002 to October 15, 2002; and detail of the 8-hour period from 00:00 to 08:00, October 15, 2002, Oahu, Hawaii.

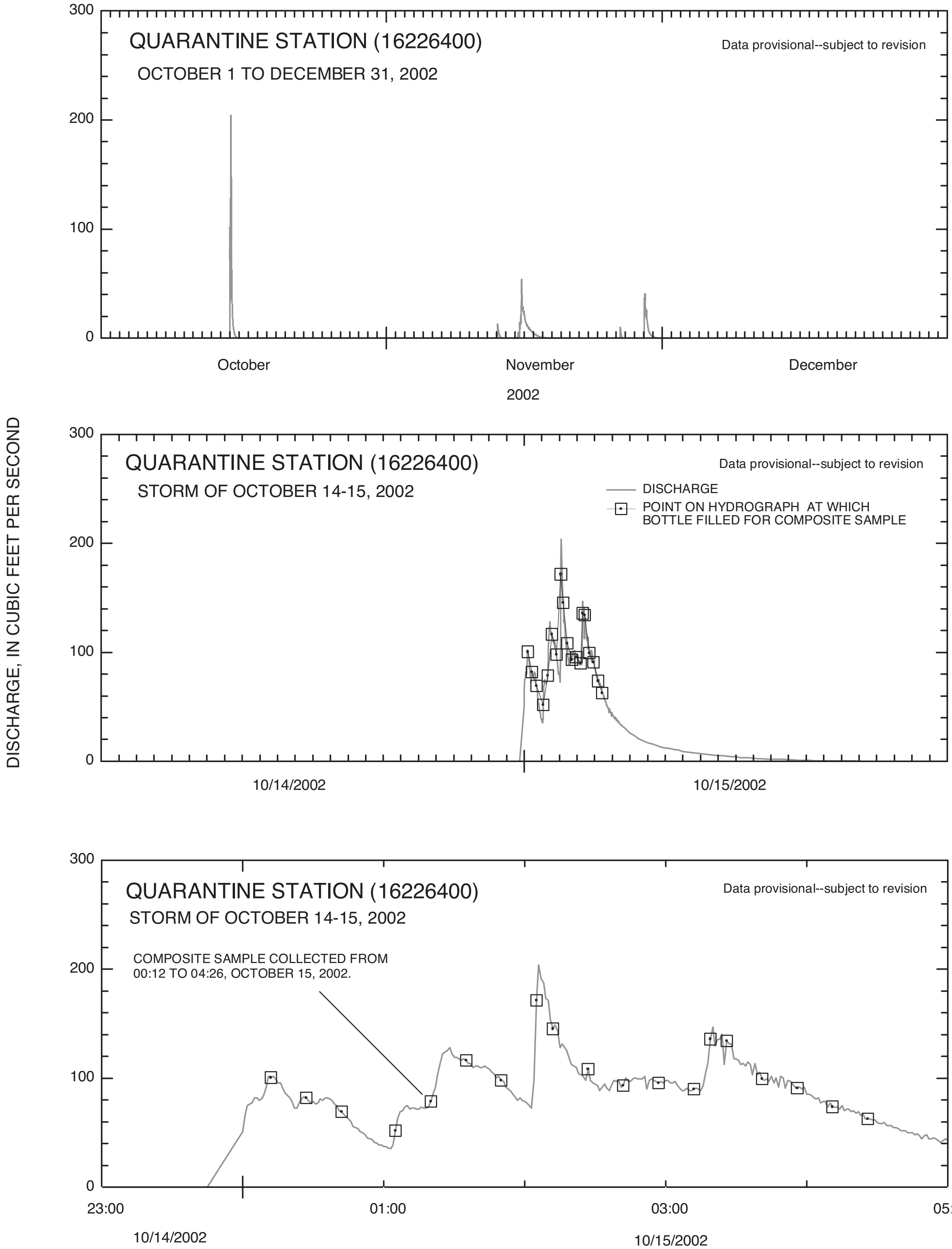

Figure 7. Stream discharge at Quarantine station (16226400) for October 1 to December 31, 2002; detail of the 2-day period from October 14, 2002 to October 15, 2002; and detail of the 6-hour period from 23:00 October 14, 2002 to 05:00, October 15, 2002, Oahu, Hawaii

The average discharge was 7.4 ft^3/s. The remaining 12 samples, collected during the last two peaks 8 hours later, were used to create a second composite sample. The peak discharges were 42 ft^3/s (00:13) and 26 ft^3/s (01:39) on October 15, 2002, respectively. The average discharge was 17 ft^3/s.

Xeriscape garden.--A total of 8 samples from the automatic sampler were used to create a flow-weighted time-composite sample from two peaks. The peak discharges were 123 ft^3/s (01:59) and 106 ft^3/s (03:12) on October 15, 2002, respectively. The average discharge for the composite sample was 76 ft^3/s. Seven of the eight samples were collected during the recession of streamflow.

Quarantine station.--A total of 19 samples from the automatic sampler were used to create a flow-weighted time-composite sample. The samples were collected during about a 4.5-hour period. The peak discharge was 204 ft^3/s on October 15, 2002 at 02:06. The average discharge for the composite sample was 96 ft^3/s.

First Quarter 2003 – January 1 to March 31, 2003

The first quarter of 2003 had more rainfall and storms than the other quarters (fig. 2). During this quarter, four storms were sampled. Complete storm samples for all five sites were collected during the storms of January 30–31, 2003 and February 14, 2003. Partial storm samples were collected during the storms of January 15, 2003 and March 16–17, 2003.

Storm of January 15, 2003

The first storm of the quarter was on January 15, 2003. This storm was of short duration and magnitude; only Storm drain C site had sufficient flow to sample. Thresholds for the Xeriscape garden and Quarantine station automatic samplers were not exceeded. Hydrographs of streamflow at Storm drain C during the storm of January 15, 2003 are shown in figure 8. The grab-sample collection time and composite-sample collection beginning and end times are displayed on the hydrograph (fig. 8). Discharges, temperature, pH, and specific-conductance values from field measurements and constituent concentrations and average loads for the grab and composite samples are shown in appendix B.

One grab sample and one composite sample were collected from Storm drain C for the storm of January 15, 2003. The grab sample was collected at the centroid of flow in the storm drain by directly submersing the churn. At the time of the grab, the discharge was 3.0 ft^3/s (fig. 8). Discharge associated with the grab sample was determined using the stage at the mean time of the grab-sample collection and the streamflow rating for this gage.

Five automatic samples were collected. The first two samples were used as grab samples for O+G and TPH analyses. A flow-weighted time-composite sample was created by combining the last three samples. The peak discharge for the composite sample was 14 ft^3/s on January 15, 2003 at 07:00. The average discharge was 8.2 ft^3/s.

Storm of January 30–31, 2003

Hydrographs of streamflow at Storm drain C, Xeriscape garden, and Quarantine station during the storm of January 30-31, 2003 are shown in figures 9, 10, and 11, respectively. The grab-sample collection time and composite-sample collection beginning and end times are displayed on the hydrographs (figs. 9–11). The measured discharges for the grab samples and average discharges during the collection of the flow-weighted time-composite samples are shown in appendix B. A total of three composite samples were collected from Storm drain C, Xeriscape garden, and Quarantine station. Grab samples were collected from all five sites during the storm of January 30–31, 2003.

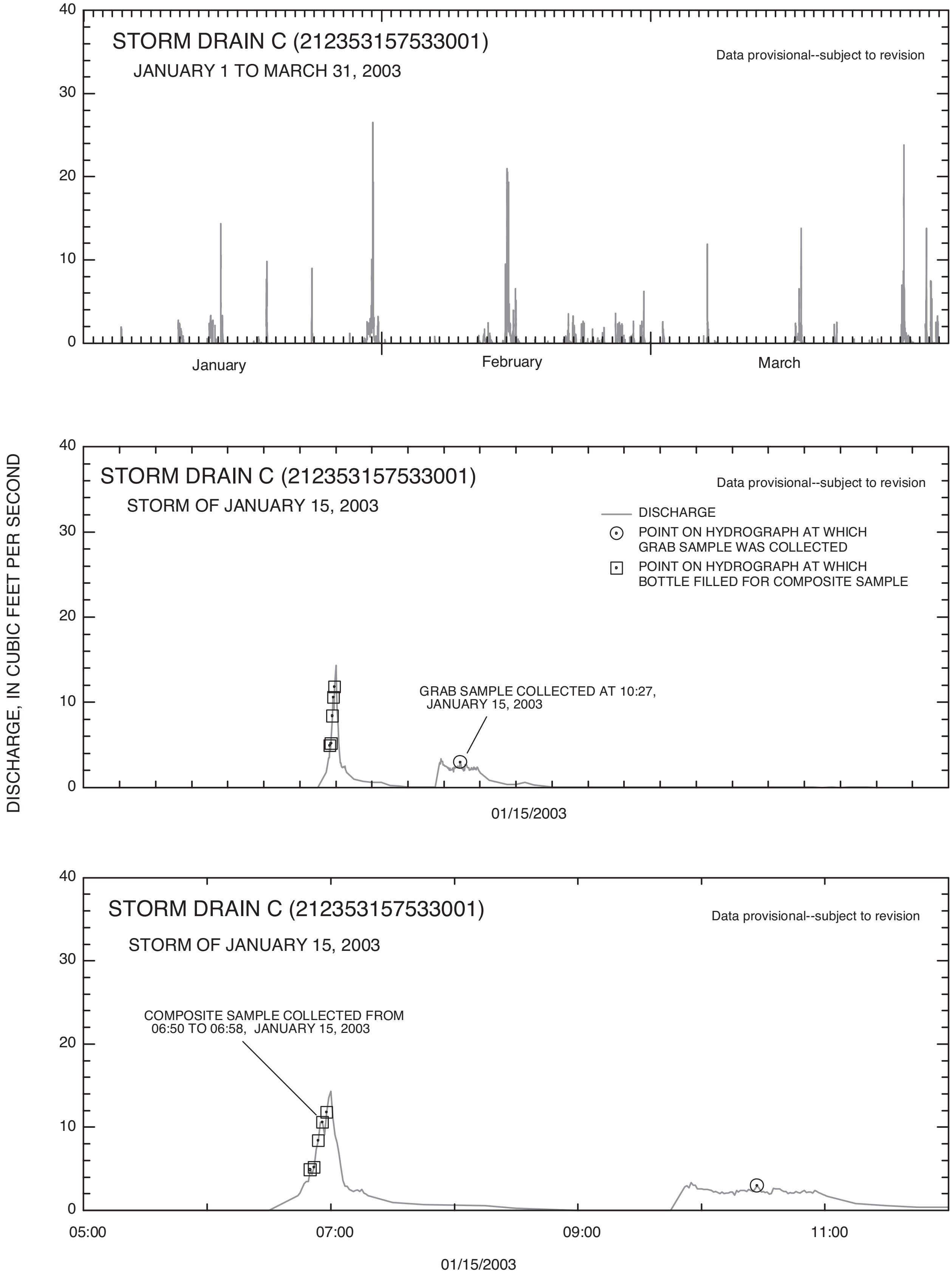

Figure 8. Stream discharge at Storm drain C station (212353157533001) for January 1 to March 31, 2003; detail of the 1-day period of January 15, 2003; and detail of the 7-hour period from 05:00 to 12:00 January 15, 2003, Oahu, Hawaii.

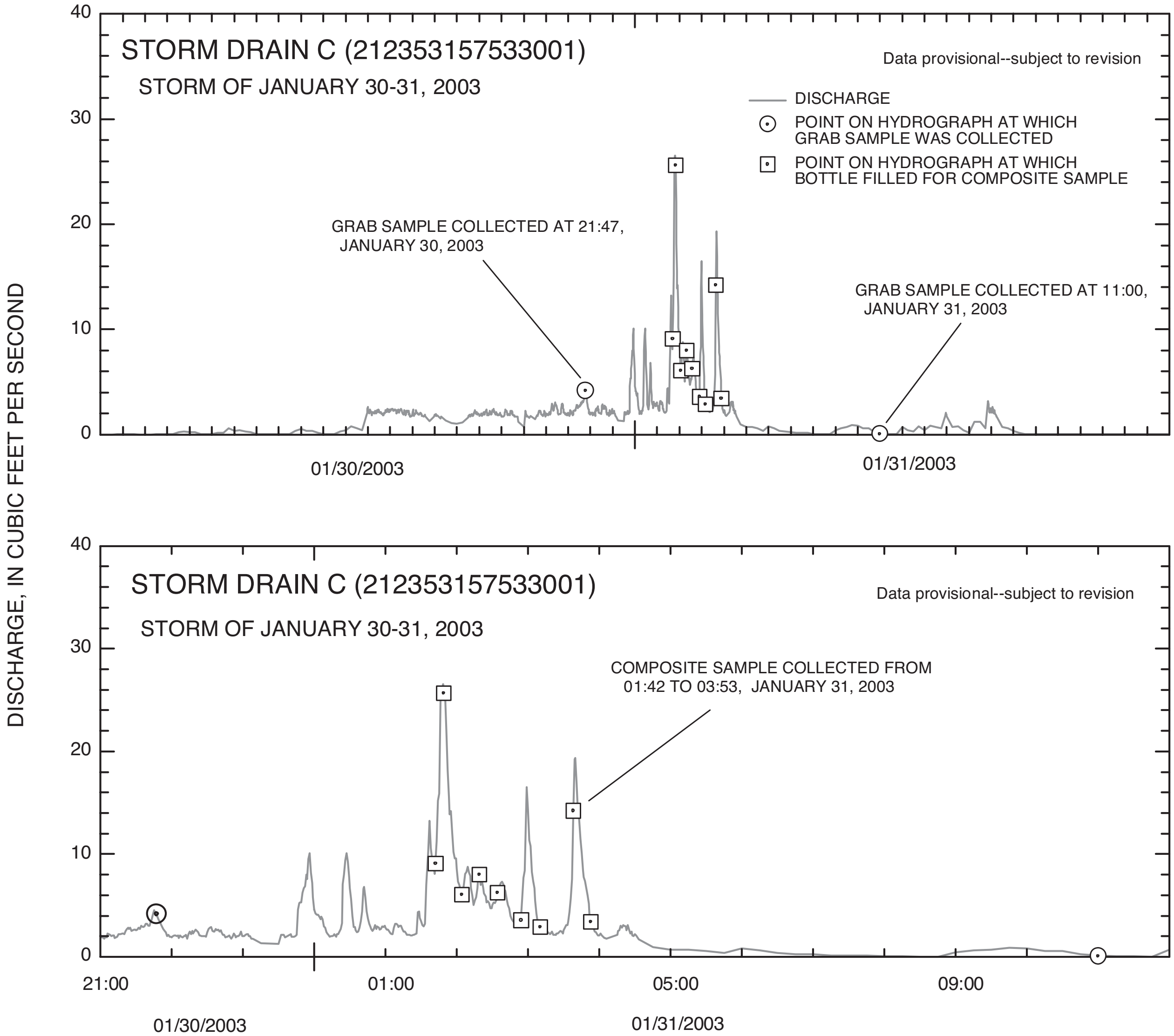

Figure 9. Stream discharge at Storm drain C station (212353157533001) for the 2-day period of January 30–31, 2003, and detail of the 15-hour period from 21:00 January 30, 2003 to 12:00 January 31, 2003, Oahu, Hawaii.

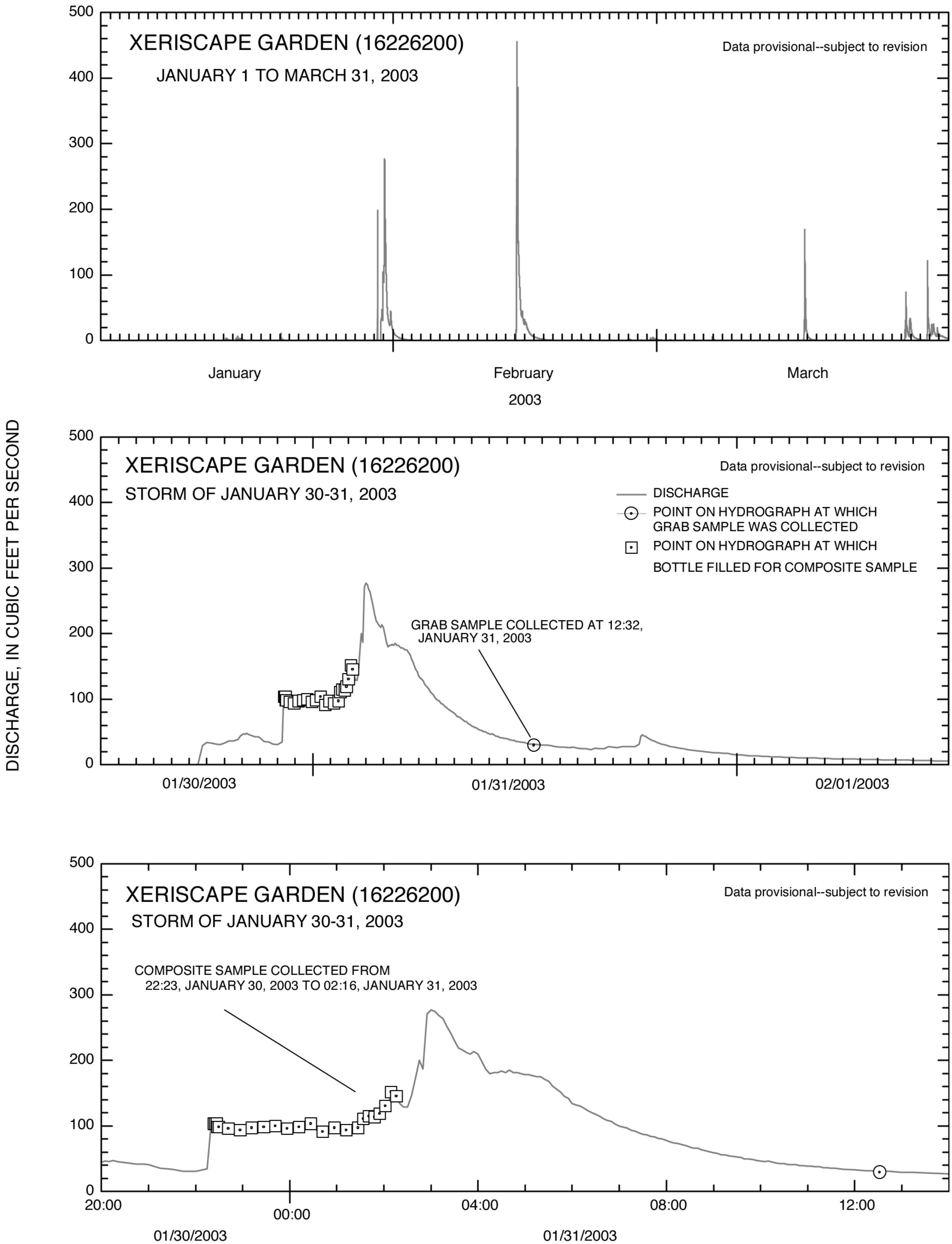

Figure 10. Stream discharge at Xeriscape garden station (16226200) for January 1 to March 31, 2003; detail of the 3-day period from 12:00 January 30, 2003 to 12:00 February 1, 2003; and detail of the 18-hour period from 20:00 January 30, 2003 to 14:00 January 31, 2003, Oahu, Hawaii.

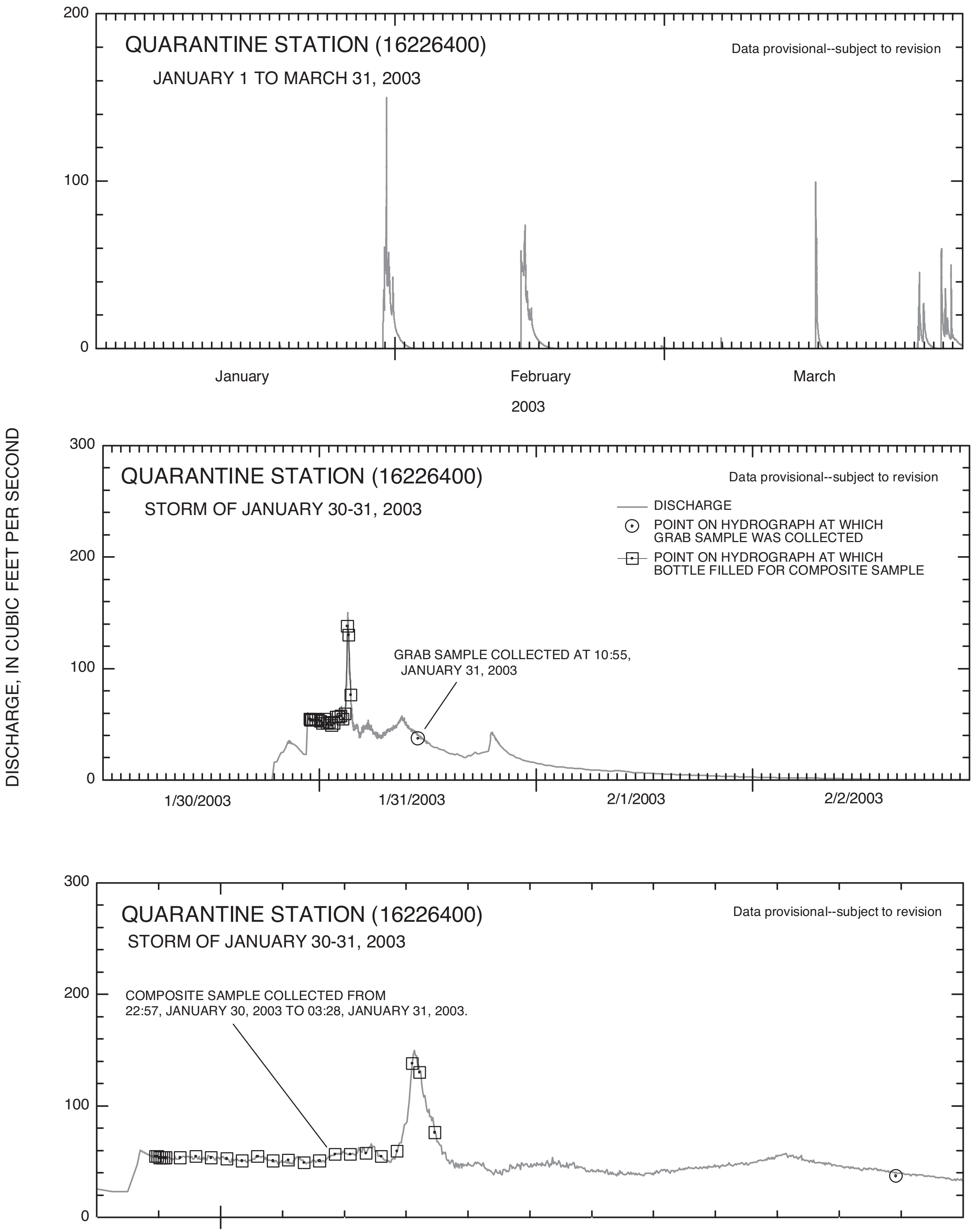

Figure 11. Stream discharge at Quarantine station (16226400) for January 1 to March 31, 2003; detail of the 4-day period from January 30, 2003 to February 2, 2003; and detail of the14-hour period from 22:00 January 30, 2003 to 12:00 January 31, 2003, Oahu, Hawaii.

Bridge 8.--A grab sample was collected using the EWI method at 10 sampling points spaced every 2 ft along a cross section of the stream. The stream width was about 20 ft, and the discharge was concentrated in the middle 6 ft of the cross section used for sampling. An isokinetic sampler was used to collect the sample. A field duplicate was collected at this site. Discharge was measured concurrently with the sample collection using a current meter and was 42.7 ft^3/s.

Storm drain C.--Two grab samples were collected. The first 5 automatic samples, representing the first flush, were analyzed as a grab sample, but was flow-weighted. These samples were collected on January 30, 2003. The average discharge was 4.2 ft^3/s (fig. 9). The second grab sample was collected at the centroid of flow in the storm drain by directly submersing the churn. At the time of the manual-grab sample, the discharge was 0.04 ft^3/s (fig. 9). Discharge associated with the grab sample was determined using the stage at the mean time of the grab-sample collection and the streamflow rating for this gage.

The automatic sampler collected a total of 17 samples during a 6-hour period. The first 5 automatic samples were used for the first grab sample, as mentioned above. The next 3 samples were omitted due to the large time difference between each of the 3 samples, and the first 5 samples and the following 9 samples. The time differences ranged from 16 minutes to 2 hours. The composite consisted of the last 9 samples collected during a 2.5-hour period. The peak discharge was 27 ft^3/s on January 31, 2003 at 01:48. The average discharge was 7.2 ft^3/s.

Xeriscape garden.--The grab sample was collected using the EWI method at 11 sampling points distributed every 2 ft along the cross section of the stream. Stream width was about 23 ft. An isokinetic sampler was used to collect the sample. A laboratory spike sample was collected at this site. Discharge was measured concurrently with the sample collection using a current meter and was 29.3 ft^3/s. FC and BOD samples were collected at this site, but were not analyzed because the laboratory holding times were exceeded.

Twenty-four samples from the automatic sampler were used to create a flow-weighted, time-composite sample. The peak discharge was 277 ft^3/s on January 31, 2003 at 03:10. The samples were collected during the initial rise of the stream (fig. 10). The average discharge for the composite sample was 94 ft^3/s.

Quarantine station.--The grab sample was collected using the EWI method at 7 sampling points distributed every 2 ft along the cross section of the stream. Stream width was about 15.0 ft. An isokinetic sampler was used to collect the sample. Sample water from this site was also used for a laboratory duplicate sample. Discharge, measured concurrently with sample collection using a current meter, was 37.0 ft^3/s.

Twenty-four samples collected by the automatic sampler were used to create a flow-weighted, time-composite sample. The peak discharge was 150 ft^3/s on January 31, 2003 at 03:08. The samples were collected during a rise and fall of the stream. The average discharge was 61 ft^3/s.

Stadium.--A grab sample was collected at 9 sampling points using a HDPE 1-liter open-mouth bottle because of the shallow depths and swift moving water in the concrete-lined channel. The stream width was about 61 ft. Discharge, measured using a current meter, was 60.1 ft^3/s.

Storm of February 14, 2003

Hydrographs of streamflow at Storm drain C, Xeriscape garden, and Quarantine station during the storm of February 14, 2003 are shown in figures 12, 13, and 14, respectively. The grab-sample collection time and composite-sample collection beginning and end times are displayed on the hydrographs (figs. 12–14). The discharges for the grab samples and flow-weighted time-composite samples are shown in appendix B.

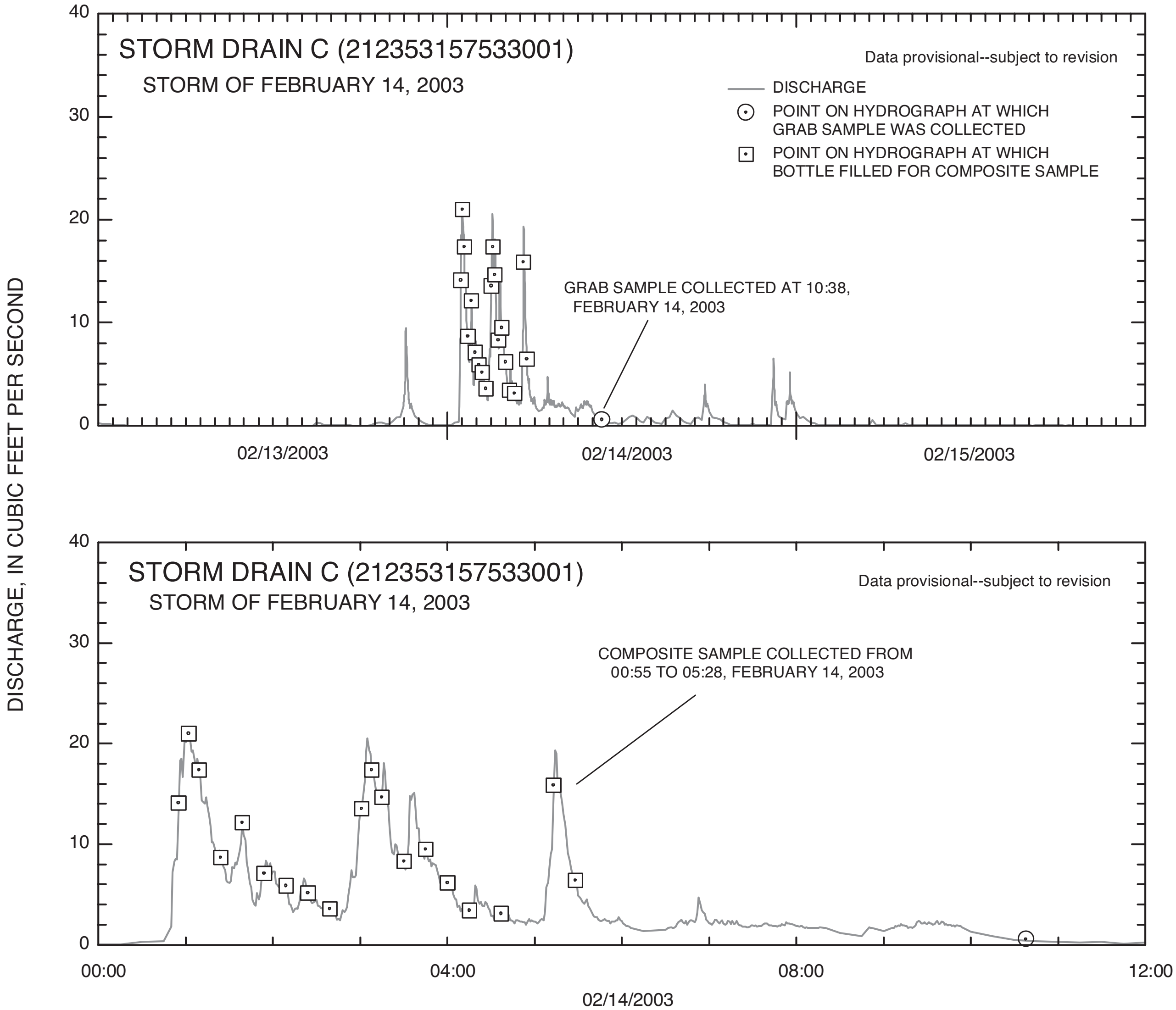

Figure 12. Stream discharge at Storm drain C station (212353157533001) for the 3-day period of February 13–15, 2003, and detail for the 12-hour period from 00:00 to 12:00 February 14, 2003, Oahu, Hawaii.

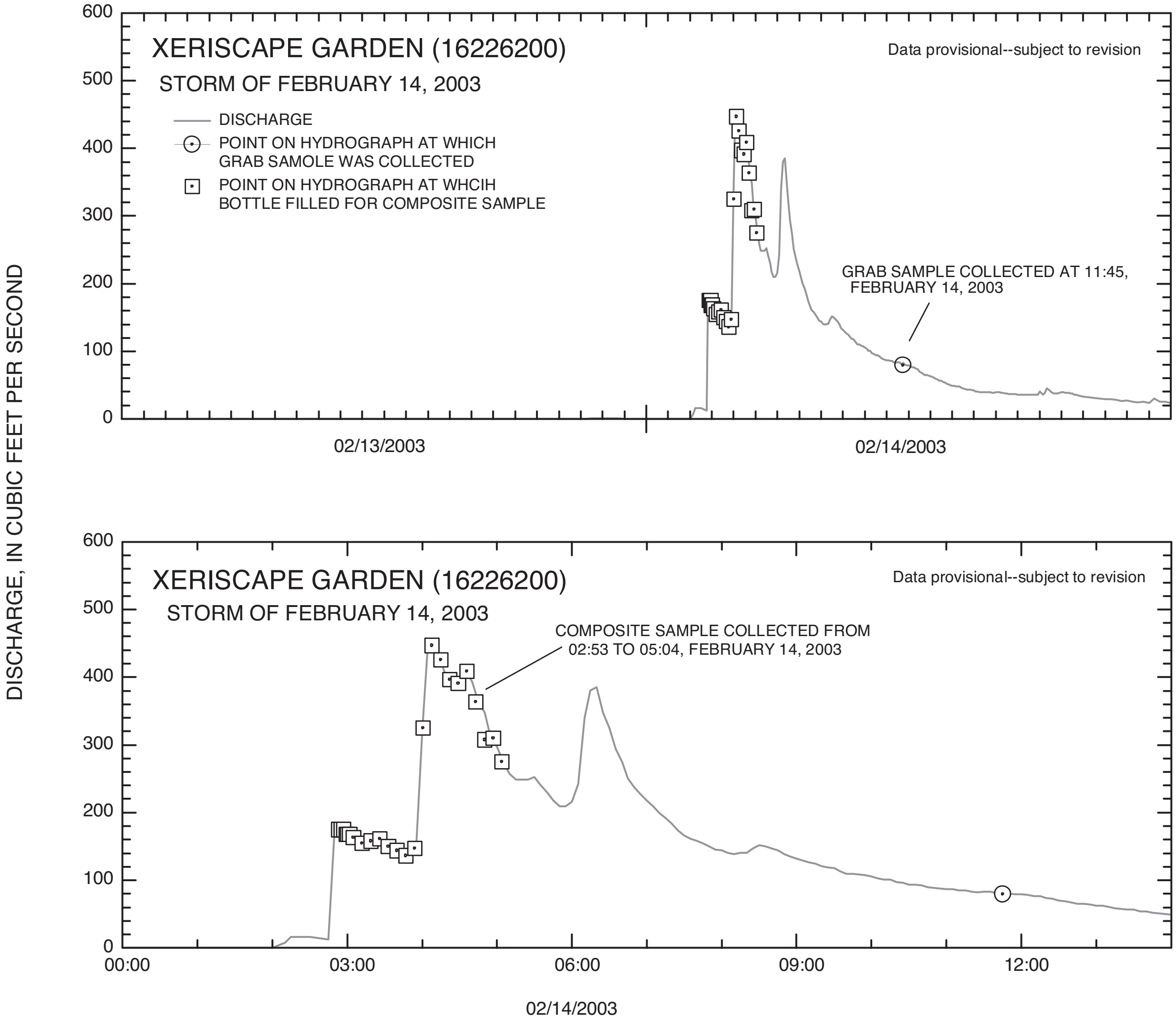

Figure 13. Stream discharge at Xeriscape garden station (16226200) for the 2-day period of February 13–14, 2003, and detail of the 14-hour period from 00:00 to 14:00 February 14, 2003, Oahu, Hawaii.

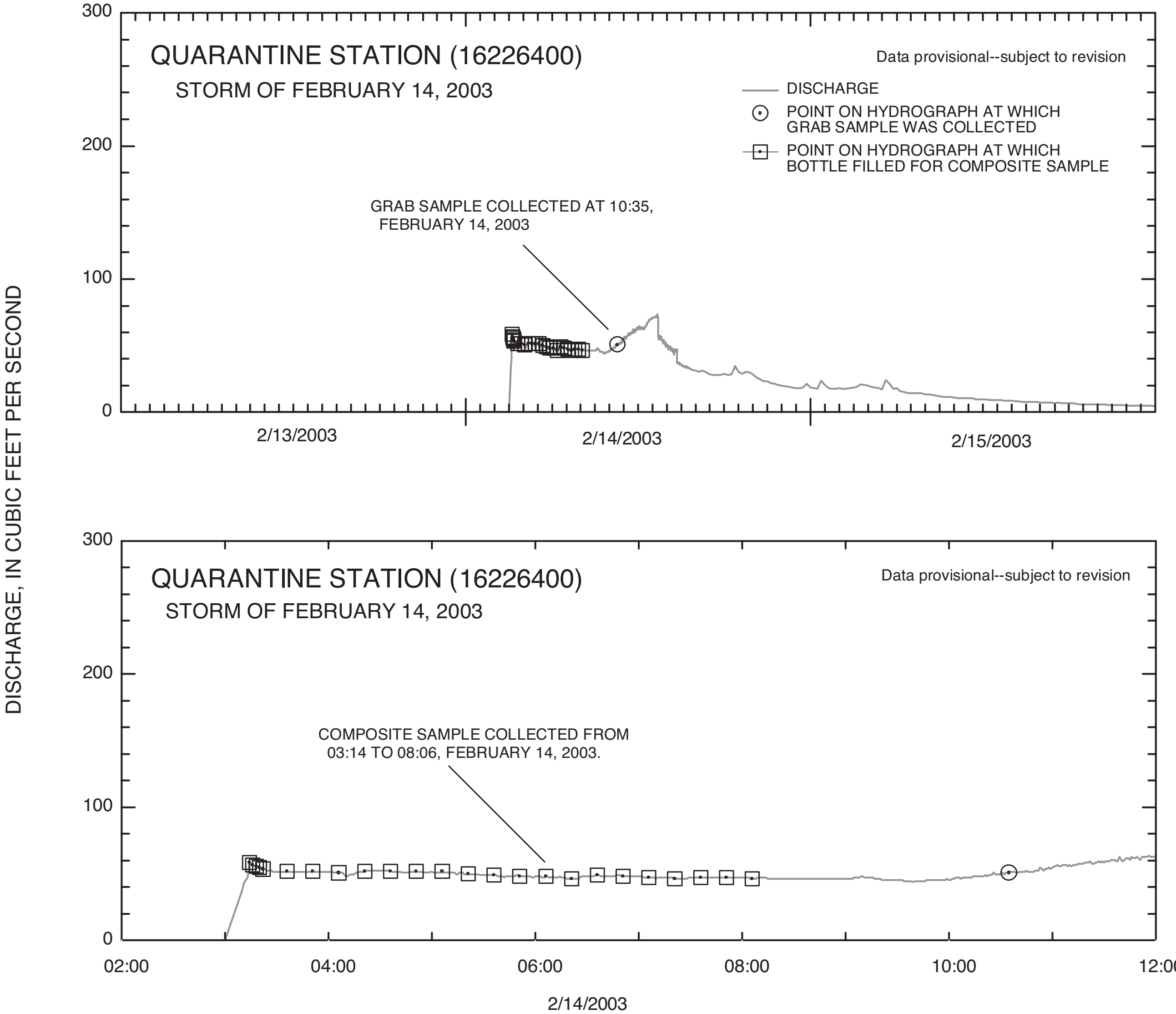

Figure 14. Stream discharge at Quarantine station (16226400) for the 3-day period of February 13–15, 2003, and detail of the 10-hour period from 02:00 to 12:00 February 14, 2003, Oahu, Hawaii.

Three composite samples were collected from Storm drain C, Xeriscape garden, and Quarantine station. Grab samples were collected from all five sites during the storm of February 14, 2003.

Bridge 8.--A grab sample was collected along a single vertical section at the estimated fastest and deepest section of the stream. Discharge was concentrated in the middle 6 ft of the cross section used for sampling. An isokinetic sampler attached to an aluminum pole was used to collect the sample. A field duplicate was collected at this site. Discharge associated with the grab sample was determined using the streamflow rating for this site and was 47 ft^3/s.

Storm drain C.--A grab sample was collected at the centroid of flow in the storm drain by directly submersing the churn. Discharge associated with the grab sample was determined using the stage at the mean time of the grab sample collection and the streamflow rating for this gage. Discharge was 0.56 ft^3/s. A flow-weighted time-composite sample was created by combining 19 samples from the automatic sampler. These samples were collected during about a 4.5-hour period. The peak discharge was

21 ft^3/s on February 14, 2003 at 01:02. The average discharge was 9.4 ft^3/s.

Xeriscape garden.-- A grab sample was collected along a single vertical section at the estimated fastest and deepest section of the stream. An isokinetic sampler was used to collect the sample. A laboratory spike sample was collected at this site. Discharge associated with the grab sample was determined using the stage at the mean time of grab-sample collection and the streamflow rating for this gage. Discharge was 79 ft^3/s.

Twenty-four samples from the automatic sampler were used to create a flow-weighted time-composite sample. The samples were collected during the rise, peak, and recession of the stream (fig. 13). The peak discharge was 456 ft^3/s on February 14, 2003 at 04:05. The average discharge was 265 ft^3/s.

Quarantine station.--A grab sample was collected along a single vertical section at the estimated fastest and deepest section of the stream. An isokinetic sampler was used to collect the sample. Sample water from this site was also used for a laboratory duplicate sample. Discharge associated with the grab sample was determined using the stage at the mean time of grab-sample collection and the streamflow rating for this gage. The discharge was 51 ft^3/s.

All 24 samples collected by the automatic sampler were used to create a flow-weighted, time-composite sample. The samples were collected during the initial rise of the stream. The peak discharge was 73 ft^3/s on February 14, 2003 at 13:15. The average discharge was 49 ft^3/s.

Stadium.--A grab sample was collected using the EWI method at 11 sampling points, spaced about 5 ft apart, along the cross section of the concrete-lined channel. An isokinetic sampler attached to an aluminum pole was used to collect the sample. The stream width was about 73 ft. Discharge, measured by the float method, was 235 ft^3/s.

Storm of March 16–17, 2003

Hydrographs of streamflow at Storm drain C, Xeriscape garden, and Quarantine station during the storm of March 16–17, 2003 are shown in figures 15, 16, and 17, respectively. Grab sample-collection times and composite-sample collection beginning and end times are displayed on the hydrograph (figs. 15–17). Discharges and analyzed constituents are shown in appendix B. Analyses for nutrient and chemical oxygen demand were not done after holding times were exceeded when a Denver airport closure delayed the sample shipment.

Two composite samples were collected from Xeriscape garden and Quarantine station, and three grab samples were collected from Storm drain C, Xeriscape garden, and Quarantine station sites during the storm of March 16–17, 2003. Discharges at Bridge 8 and Stadium were too low for grab sample collection.

Storm drain C.--Manual grab samples were not collected. The automatic sampler collected five samples over a 5-hour period during the storm of March 16–17, 2003. The first two samples were not used because of the large time difference (5 hours) between these and the last three samples. The last three samples were treated as a grab sample and assigned a median time of 16:13 and a time-weighted discharge of 6.4 ft^3/s (fig. 15). This grab sample was not analyzed for O+G, TPH, FC, and BOD. The peak discharge was 14 ft^3/s on March 16, 2003 at 16:08.

Xeriscape garden.--A grab sample was collected using the EWI method at 14 sampling points distributed every 0.5 ft along the cross section of the stream. Stream width was about 7.7 ft. An isokinetic sampler was used to collect the sample. A laboratory spike sample was collected at this site. Discharge, measured concurrently with the sample collection using a current meter, was 1.99 ft^3/s.

Thirteen samples from the automatic sampler were used to create a flow-weighted time-composite sample. The samples used for the composite sample were collected during the recession of streamflow (fig. 16). The peak discharge was 170 ft^3/s on March 16, 2003 at 17:55. The average discharge for the composite sample was 82 ft^3/s.

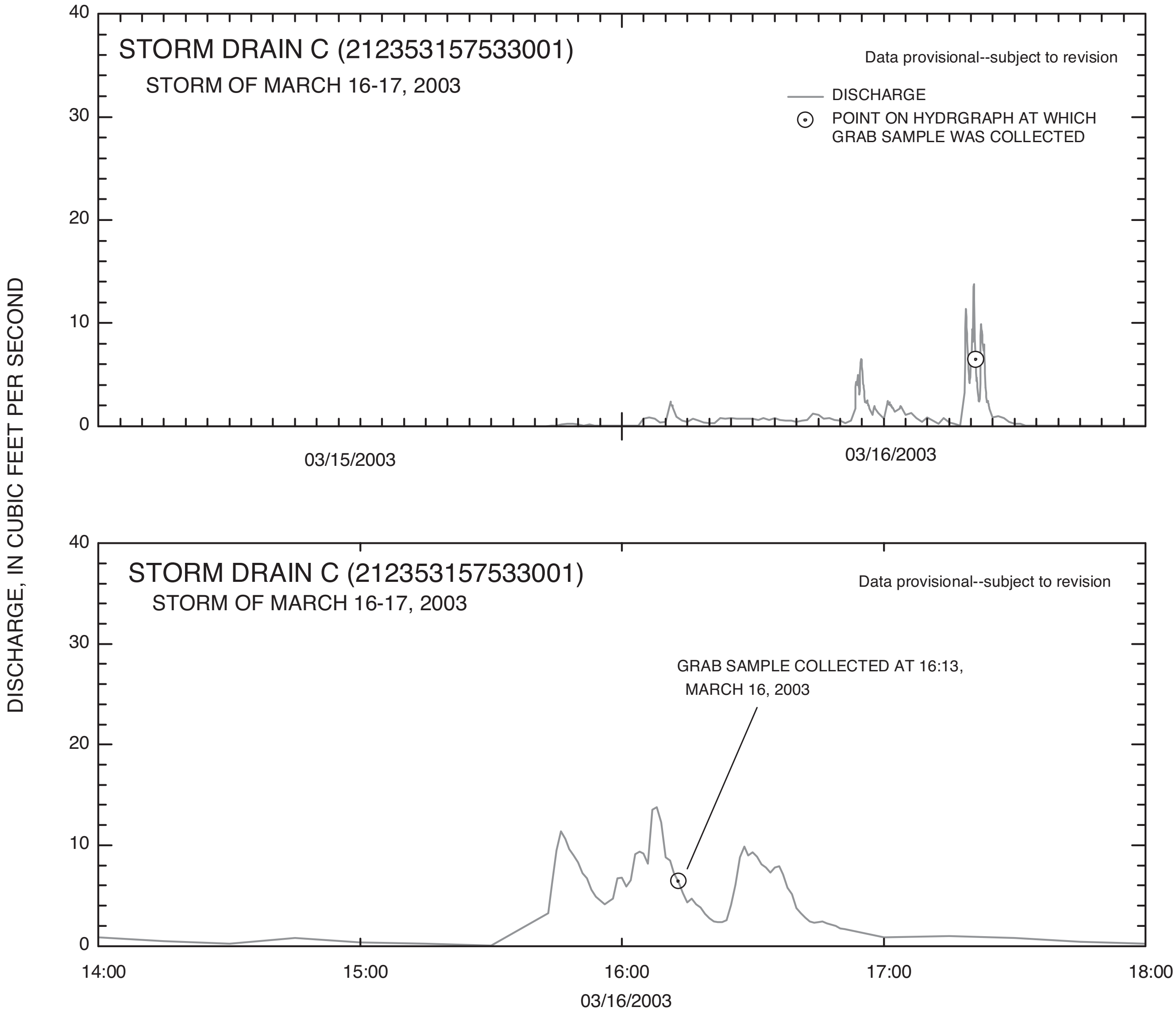

Figure 15. Stream discharge at Storm drain C station (212353157533001) for the 2-day period of March 15–16, 2003, and detail of the 4-hour period from 14:00 to 18:00, March 16, 2003, Oahu, Hawaii.

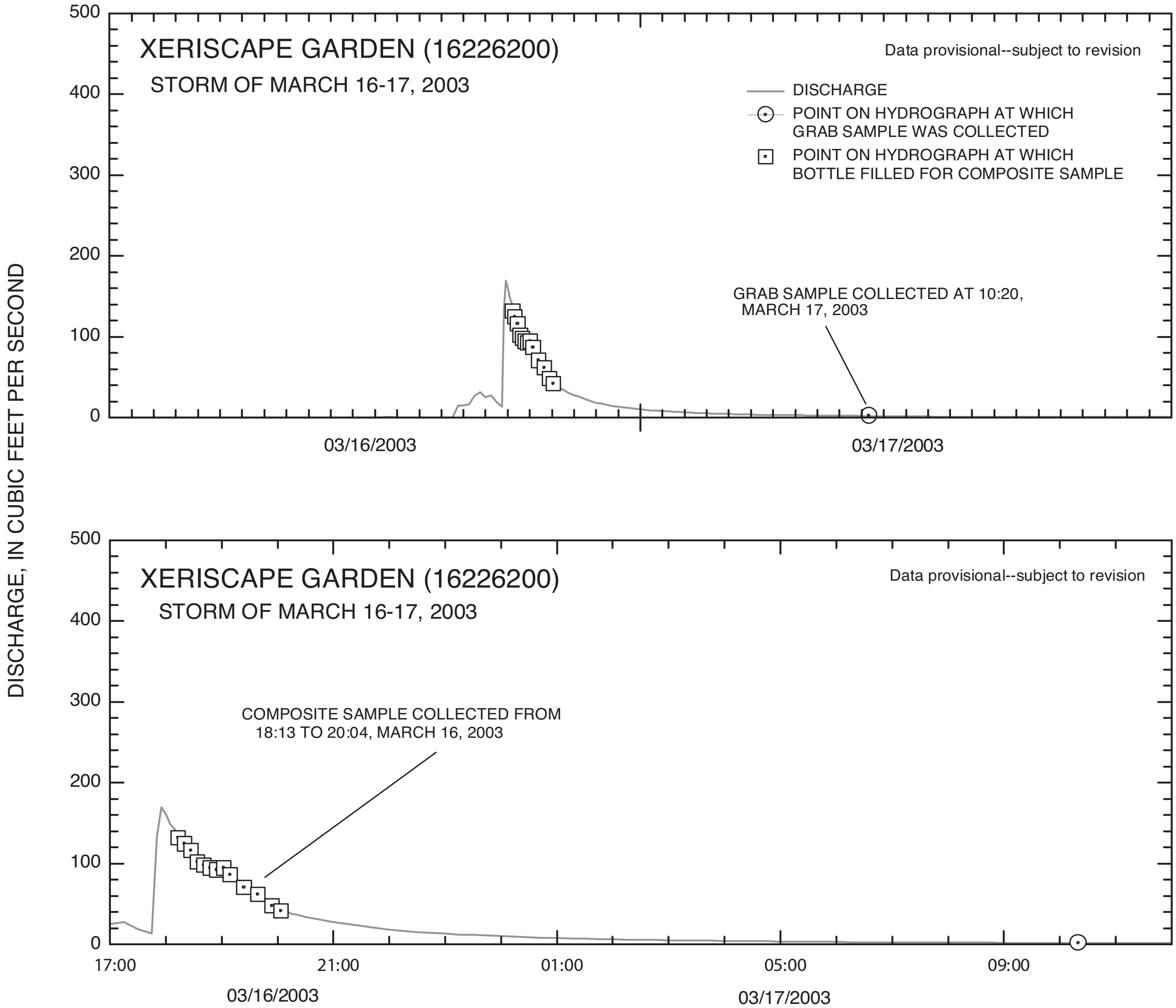

Figure 16. Stream discharge at Xeriscape garden station (16226200) for the 2-day period of March 16–17, 2003, and detail of the 19-hour period from 17:00, March 16, 2003 to 12:00, March 17, 2003, Oahu, Hawaii.

Quarantine station.—A grab sample was collected at 5 sampling points distributed every 0.5 ft along a cross section of the stream. Stream width was about 3.0 ft. A HDPE 1-liter open-mouth bottle was used to collect the sample due to insufficient depths (less than 0.5 ft) for the isokinetic sampler. Sample water from this site was also used for a laboratory-duplicate sample. Discharge, measured concurrently with the sample collection using a current meter, was 0.78 ft^3/s.

Twelve samples were collected by the automatic sampler, and were used to create a flow-weighted time-composite sample. The samples were collected at the peak and during the recession of streamflow. The peak discharge was 100 ft^3/s on March 16, 2003 at 1809 hours. The average discharge for the composite sample was 65 ft^3/s.

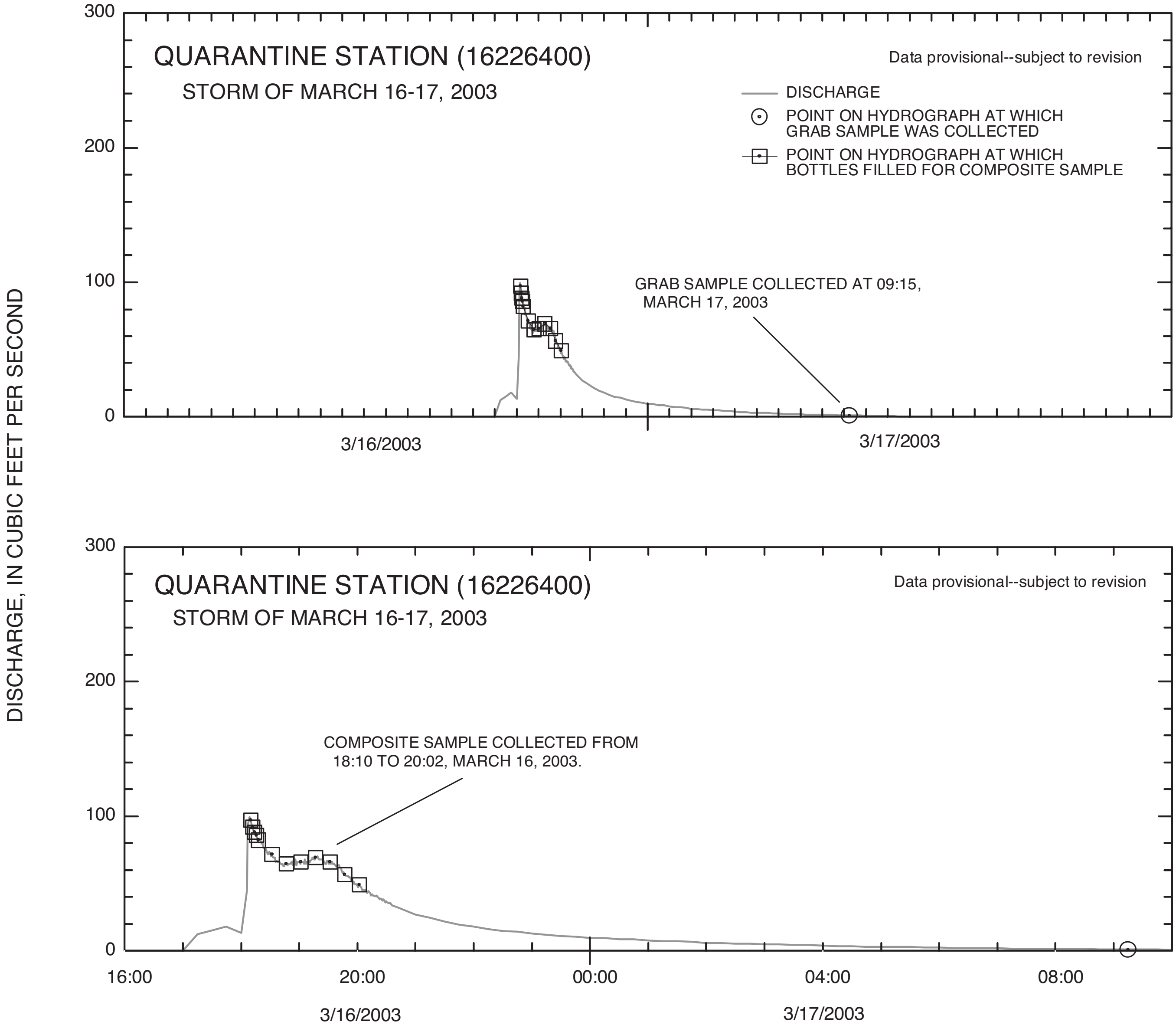

Figure 17. Stream discharge at Quarantine station (16226400) for the 2-day period of March 16–17, 2003, and detail of the 18-hour period from 16:00 March 16, 2003 to 10:00, March 17, 2003, Oahu, Hawaii.

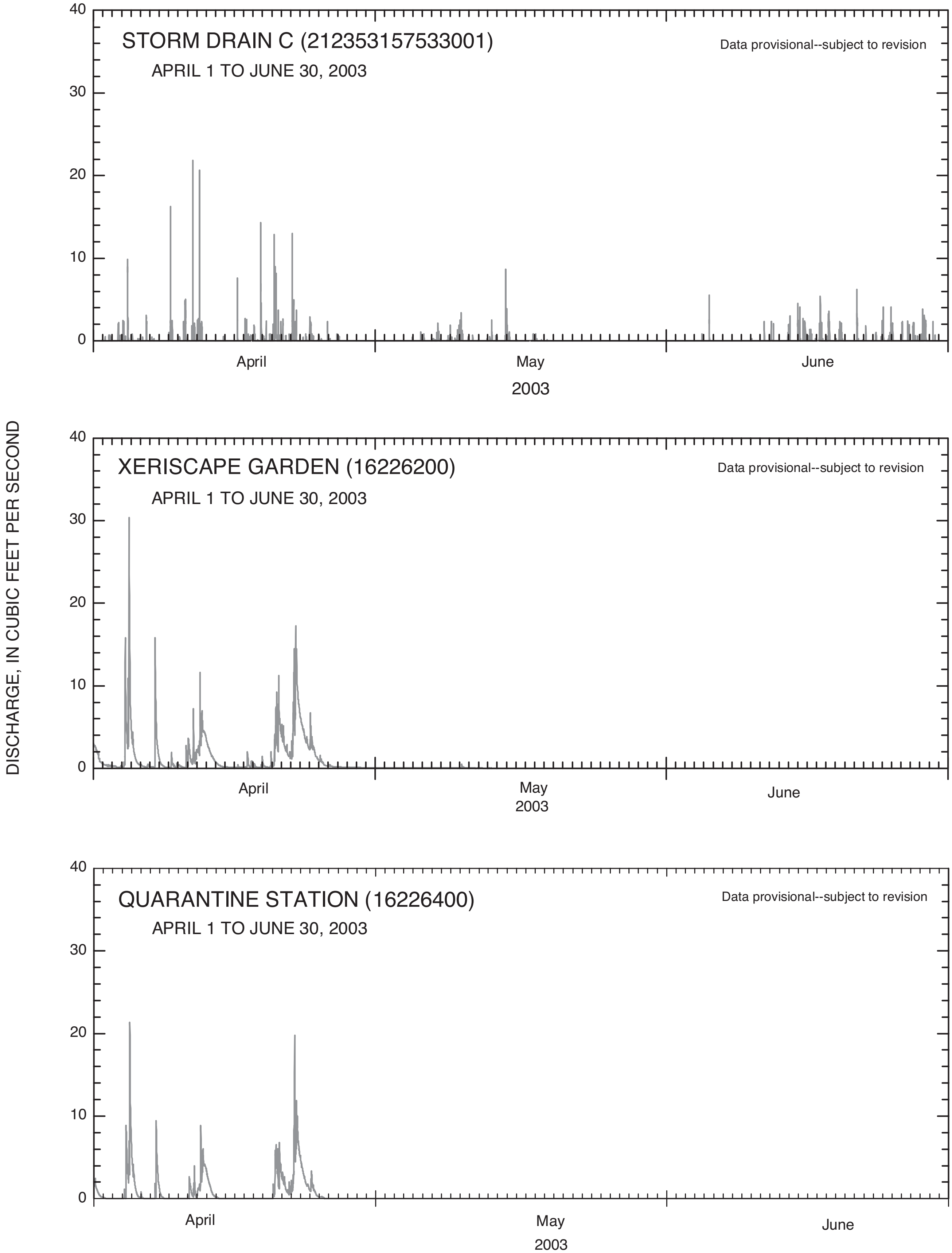

Figure 18. Stream discharge at Storm drain C, Xeriscape garden, and Quarantine stations for April 1 to June 30, 2003, Oahu, Hawaii.

Second Quarter 2003 – April 1, 2003 to June 30, 2003

Hydrographs of streamflow at Storm drain C, Xeriscape garden, and Quarantine station for the period of April 1, 2003 to June 30, 2003 are shown in figure 18. During this period, automatic sampler thresholds at all the sampling sites were not exceeded, except at Storm drain C. However, no rainfall event generated enough flow at Storm drain C, to collect a sufficient number of samples for analysis.

QUALITY ASSURANCE

Field and laboratory quality-assurance procedures were implemented as described in the DOT Storm Water Monitoring Program Plan (State of Hawaii Department of Transportation Highways Division, 2002). Twelve quality-assurance samples were collected: 8 samples were collected concurrently with storm samples during four of the storms, and 4 samples were collected between storms during routine cleaning of the sampling equipment. During storm sampling, field duplicate samples, laboratory duplicate samples, and laboratory spike samples were collected at designated sampling sites for each storm. Results are not published in this report, but are available upon request.

All grab-sample collection equipment was cleaned before each storm and sampling. The automatic-sampler intake line from Storm drain C was cleaned 6 times during the year. However, due to the pattern of discharge in Storm drain C, the sampler was triggered occasionally and samples were collected during brief rain showers, contaminating the intake line prior to subsequent storms. The intake line was contaminated in this manner prior to the October 14–15, 2002 storm at Xeriscape garden and Quarantine station, and March 16–17, 2003 storm at Storm drain C.

With regard to potential contamination problems with the intake lines, it is important to note that the automatic sampler conducts a rinse cycle prior to every sample collected. The rinse cycle routine is as follows: (1) sample line is first purged by air, (2) water is pumped up the line to a sensor located before the pump, (3) water is purged out, and (4) the sample is then collected. The rinse cycle minimizes possible contamination from water pumped during earlier storms and from previously pumped samples during the same storm.

IBW field blank samples from the automatic samplers were collected quarterly at: Storm drain C on November 13, 2002 and June 19, 2003; Xeriscape garden on November 13, 2002; and Quarantine station on February 27, 2003. Intake lines were cleaned prior to the collection of IBW field blank sample. These field samples were analyzed for nutrients, cadmium, copper, lead, and zinc. Zinc was detected in all the blank samples collected on November 13, 2002 at Xeriscape garden and Storm drain C. Concentrations of zinc ranged from 2 to 6 µg/L. The minimum reporting level of zinc is 2 µg/L. Nitrogen, total organic plus ammonia was detected at Storm drain C and Xeriscape garden for the November 13, 2002 field blank sample. The concentrations of nitrogen, total organic and ammonia at Storm drain C and Xeriscape garden were 0.070 mg/L and 0.076 mg/L, respectively. The minimum reporting levels for nitrogen, total organic plus ammonia is 0.1 mg/L.

In addition to IBW field blank samples collected on February 27, 2003, organic blank water field samples were collected from a teflon bag and a LDPE bag to compare and determine if there was any potential organic contamination from these bags. Results showed no organic contamination from the Teflon and LDPE bags.

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APPENDIX A: DISCHARGE REPORTING AND LOAD CALCULATION METHODS

This appendix further defines the methods used for reporting discharge data and constituent concentration data, and the methods for calculating of constituent loads. Data is seldom exact. To adequately qualify the quality of discharge and water-quality data, values are rounded off to the number of significant figures that best describe the precision of the measurement.

Discharge data.--Table 2 shows the number of significant figures and rounding limits for the range of discharges in this study. Discharges measured by current meter or float measurement techniques follow guidelines for measured discharges. Discharges determined by streamflow rating or by averaging follow guidelines for daily mean discharges (Sauer, 2002). Measured discharges have more significant figures because they are considered more precise to more significant figures than averaged discharges.

Calculation of loads.--Table 3 shows the conversion factors used for determining constituent loads. Constituent loads for all analyses are reported as pounds per day (lbs/day) except for fecal coliform, which is reported as billion colonies per day. All loads are the product of constituent concentration multiplied by associated discharge and the appropriate conversion factor. Concentrations are reported in milligrams per liter (mg/L) or micrograms per liter (μg/L), except for fecal coliform, which is reported in most probable number (of colonies) per 100 milliliters (MPN/100 ml). Four significant figures are used for the conversion factors, however, the load value is reported with the lesser number of significant figures of the values of concentration and discharge.

Table 2. Significant figures and rounding limits for measured, streamflow rating, and averaged discharges

[ft^3/s, cubic feet per second; <, actual value is less than shown; ≥ , actual value is greater than or equal to value shown]

Range of discharge (ft^3/s)	Measured discharge		Streamflow rating and averaged discharges	
	Significant figures	Rounding limits	Significant figures	Rounding limits
<0.10	2	thousandths	1	hundredths
0.10 to 0.99	2	hundredths	2	hundredths
1.0 to 9.9	3	hundredths	2	tenths
10 to 99	3	tenths	2	units
≥100	3	variable	3	variable

Table 3. Conversion factors for converting constituent concentration and discharge data to daily loads

[mg/L, milligrams per liter; mg/L, micrograms per liter; MPN/100 mL, most probable number of colonies per 100 milliliters; lbs/day, pounds per day]

Unit of concentration	Conversion factor	Load unit
mg/L	5.394	lbs/day
µg/L	0.005394	lbs/day
MPN/100 mL	0.02447	billion colonies per day

Appendix B. Physical Properties, Concentrations, And Loads For All Samples Collected From Halawa Stream Drainage Basin During The Period From July 1, 2002 To June 30, 2003, Oahu, Hawaii Appendb.xls